

# Correlates of Ghanaian households' use of clean cooking fuels: insight from the 2014 demographic and health surveys

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## Research article

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# Abstract

**Background:** Globally, about 2.9 billion persons, the majority of whom are from low and middle-income countries, depend on poorly combusted biomass and coal for cooking and heating. Given the negative toll the use of poorly combusted fuels have on people's health and quality of life, homes are admonished to use for cooking clean fuels that promote optimal health such as liquefied petroleum gas (LPG), natural gases, electricity, and improved biomass cook-stoves. The use of clean cooking fuels has other co-benefits such as reduce deforestation and lower climate-changing emissions. Although information on the prevalence of access to clean cooking energy is known, studies on the social, economic, and geographic factors that may explain the low adoption in households are rare. In this paper, we aim to determine the major covariates of households' access to clean cooking energy in Ghana.

**Methods:** The study used the data of the cross-sectional demographic and health surveys conducted in 2014. Chi-square test of independence was used to identify the covariates that were statistically significant related to households' use of CF&HPFs for the multivariable model. In the multivariable model, we reported prevalence ratios using the generalized linear model (glm), setting the family to "Poisson" and the link to "log." The estimation adjusted for the study designed and the household sampling weights.

**Results:** The main finding was that rich households were 8.85 times likely to use CF&HPFs compared to poor households. We further found that the following factors were associated with a higher probability of a Ghanaian household to use climate-friendly and health-promoting fuels for cooking: male-headed households, households' headed by persons between 24years and 55 years, households with heads that were currently married or never married, households with heads that have attained at least a primary level education, households with less than eight members, households with at least two women, and households in Western, Central, Greater Accra, Volta, Eastern, Ashanti, Brong Ahafo, Upper East region.

**Conclusion:** In view of these findings, we recommend: a national effort to subsidize and make affordable the purchase of LPG and the stoves that burn it even to the poorest household; education on efficient and sustainable consumption must be intensified and incorporated in the basic school's curriculum to ensure the future generation are more environmental sustainability and health-conscious; creation of multiple LPG refilling outlets in all the regions in Ghana.

## Background

Home cooking, an essential activity that primarily promotes human health and growth, is facilitated by the combustion of fuel. The type of fuel used in cooking can either support or obstruct its primary purpose. Fuels that are beneficial to human health, preferably, should undergo complete combustion process [1]. Globally, about 2.9 billion persons, the majority of whom are from low and middle-income countries, depend on poorly combusted biomass and coal for cooking and heating [2]. In Ghana, it is estimated that about eight out of ten households rely on traditional biomass for cooking and heating [2].

These fuel types emit health and climate destructive pollutants such as carbon dioxide, carbon monoxide, benzene, butadiene, nitrogen oxides, formaldehyde, polynuclear aromatic hydrocarbons, and fine particulate matter [3, 4]. Globally, household cooking and heating account for 58% of global black carbon emissions [5].

Prolonged exposure to the by-products of poorly combusted fuels is associated with unimaginably high morbidity and mortality records among the aged, adults, and children [1, 2, 6]. About 4 million persons, 54% of whom are women and children, lose their lives annually from using poorly combusted fuels [2]. Incomplete combusted products can adversely affect household air quality, resulting in a myriad of adverse health effects among children and women [1, 2, 6]. This polluted home environment is associated with acute lower respiratory infections such as pneumonia and bronchitis in children [1, 6]. This environment equally contributes to increased risk of chronic obstructive pulmonary disease and various types of cancer, and poor pregnancy outcomes such as low birth weight and neonatal deaths among women [1].

The use of traditional biomass fuels poses several threats to the ecosystem and the protection they provide [7]. The human activity of tree harvesting for fuel leads to forest degradation with extended negative effects on biodiversity, soil stability, and water quality and quantity [7]. The production and use of charcoal for household cooking, for instance, produces climate-altering pollutants (CAPs) such as black carbon and carbon dioxide [8]. The protection trees and green vegetation provide is that they absorb atmospheric carbon dioxide, the prominent CAP, for photosynthesis [7]. Therefore, the harvesting of trees weakens nature's ability to effectively participate in the carbon cycle to the benefit of both the environment and human health [7, 8].

Given the negative toll the use of poorly combusted fuels have on people's health and quality of life, homes are admonished to use for cooking and heating clean fuels that promote optimal health such as liquefied petroleum gas (LPG), natural gases, electricity, and in some cases improved biomass cook-stoves [2, 4, 9]. The use of clean cooking energy sources has other co-benefits such as reduce deforestation and lower climate-changing emissions [2, 4]. Although LPG and natural gas are fossil and burning them emit carbon, their net contribution to the global black carbon and impact on the environment are lesser compared to the burning of biomass fuels [9]. Given that electricity's climate friendliness depends on the energy sources, many countries including Ghana are making efforts to generate their electricity by using fuels that pose minimal threat to the environment. Ghana, for instance, has a total of 2520mw installed electricity generation capacity. About 47% and 13% of the electricity is entirely generated by hydropower and gas, respectively [10]. The remaining 40% is interchangeably generated through both gas and oil [10]. Therefore, the push by the International Energy Agency, the United Nations (UN), and the World Health Organization (WHO) to universally adopt these types of fuels as clean cooking solutions is in the interest of promoting human health and saving the climate [2] .

Despite the progress made by governments, non-governmental organizations, and energy advocates to use clean fuels to meet household energy needs, the current estimate suggests that 4 out of 10 people

worldwide do not have access to clean cooking energy sources [2]. Sub-Saharan Africa (SSA) has the largest clean cooking energy access deficit with only about 14% of its population having access. Although Ghana's estimate of 25% of the population having access to clean cooking energy sources is higher than the SSA average [2], it is undesirable and puts Ghana in an impossible position of achieving the SDG 7 of universal adoption of clean cooking energy by 2030.

Although information on the prevalence of access to clean cooking energy is known, studies on the social, economic, and geographic factors that may explain the low adoption in households are rare. In this paper, we aim to determine the major covariates of households' access to clean cooking energy in Ghana.

## Methods

### Design

The 2014 Ghana Demographic and Health Surveys (GDHS) data was collected in line with a cross-sectional survey design [11]. The survey employed two-stage probability sampling, stratified by urban and rural areas of the ten administrative regions of Ghana [11]. The sampling frame for the survey was based on the updated sampling frame from the 2010 Ghana Population and Housing Census [11]. The first stage of the probability sampling involved the selection of enumeration areas (EAs), which was stratified by place of residence [11]. A total of 427 EAs were selected, 216 in urban areas and 211 in rural areas [11]. The second stage of the probability sampling involved the systematic sampling of households [11]. The implementers of the survey undertook a household-listing operation in all the selected EAs from January through March 2014, and households to be included in the survey were systematically selected from the list [11]. Approximately 30 households were selected from each EA to constitute the total sample size of 12,831 households [11].

### Data collection

Trained enumerators collected the data from early September to mid-December 2014 using paper-based questionnaires [11]. The selected sample size for the 2014 GDHS was 12,831 households, of which 12,010 were occupied [11]. Out of the occupied households, 11,835 were successfully reached, resulting in a 99% response rate [11]. In the GDHS, household heads provided information on their demographic characteristics and household characteristics such as household population and composition, housing structure, household assets, access to basic utilities, sources of drinking water, water treatment practices, access to sanitation facilities, and type of fuel used for cooking [11].

### Study sample

The unit of analysis is households, and the dataset contains 11,835 households. The data were weighted using the household weight variable in the dataset. A sample of 513 households indicated that they

cooked no food in the house, so they were excluded from further analyses. Therefore, the analytic weighted sample is 11,322.

## **Variables**

### **Outcome variable:**

In the dataset, the household head was asked to select the main source of fuel for cooking in the household from the following categories: electricity, LPG, natural gas, kerosene, coal, lignite, charcoal, wood, straw/shrubs/grass, and agricultural crop. Electricity, LPG, and natural gas was defined in our study as HP & CFFs and all other sources of fuels as non-climate friendly and health promoting. Additional file shows the proportion of households using each of the fuel types for cooking in Ghana (See Additional file 1).

### **Covariates:**

Ten sociodemographic characteristics variables were selected as potential covariates in the study. Marital status was recoded as follows: never in union (as never married), married and living with partner (as currently married), widowed, divorced, and no longer living together/separated (as formally married). For the multivariable model, household wealth was dichotomized as follows: poorest, poorer, and middle (as poor) and richer and richest (as rich).

Household wealth index was already estimated and reported in the DHS data. This was created using household characteristics (source of drinking water, type of toilet, sharing of toilet facilities, main material for roof, walls and floors floor, and type of cooking fuel amongst others household characteristics) and household possessions and assets (ownership of television, radio, vehicle, bicycles, motorcycles, watch, agricultural land, farm animals/livestock, and bank account amongst others). DHS used a principal component analysis (PCA) to assign weights to each asset in each household and cumulative score were calculated from the assigned weights. Households were ranked according to the cumulative scores from the household assets. The cumulative percentage distribution of the wealth score was estimated and the wealth score values that corresponded to the four cut point values of the quintiles (20th, 40th, 60th, and 80th percentiles) were determined. Households with values less than or equal to the 20th percentile score were assigned poorest, those greater 20% but less than or equal to 40th % were assigned poorer, those greater than the 40th % and less than or equal to the 60th % score were assigned middle, greater than the 60th % and less than or equal to the 80th % score were assigned richer and the richest household were those with scores greater than the 80th percentile score. Wealth index was thus ranked into quintiles: poorest, poorer, middle, richer, and richest [12].

### **Analytic procedure**

We used STATA version 14 for the data analyses. Summary statistics, chi-square test of independence, and Poisson regression were performed. The analysis accounted for sampling design (cluster, strata) and household weights using the 'svy' command in a default mode. The default 'svy' computes standard

errors by using the linearized variance estimator called the first-order Taylor linearization. This process eliminated the incorrect estimation of the Standard Errors (SE) associated with the confidence intervals of the regression coefficients. After survey setting our data, we obtained prevalence ratios by performing Poisson regression. We achieved this by using the generalized linear model (glm) in STATA, setting the family to “Poisson” and the link to “log,” to avoid the potential overestimation of effects from reporting odds ratios when the prevalence of the outcome of interest is above 10%. The mathematical equation for Poisson regression is as follows: (see Formulas in the Supplementary Files)

The outcome variable has only two events (that is ‘0, 1’), where the value ‘1’ means a household was using clean cooking fuel and the value ‘0’ means that a household is not using clean cooking fuel.

Before performing the multivariable analysis, we check the assumption of multicollinearity and no violations were observed. The variance inflation factors of the covariates are all less than 2 (Table 1), which are far less than the cut of points of 10 [13].

**Table 1 Collinearity statistics of the covariates**

Variables	Tolerance	Variance Inflation Factor (VIF)
X1: Sex of HH	0.77	1.30
X2: Age of HH	0.89	1.12
X3: Marital status of HH	0.78	1.29
X4: The education level of HH	0.71	1.40
X5: Size of HH	0.86	1.16
X6: Number of women (15-49) in HH	0.85	1.78
X7: Number of men (15-49) in HH	0.89	1.12
X8: Household wealth	0.54	1.85
X9: Urban/rural residence	0.63	1.60
X10: Region	0.99	1.01

## Results

### *Sample Characteristics*

In the dataset, 3040 (26.9%) households were using HP & CFFs for cooking. Majority of the households were headed by males (64.9%). Most of the household heads were currently married (62.9%). The summary statistics for the remaining study variables are reported in Table 2.

**Table 2: Summary statistics of study variables**

Variables	n(%)
<b>HP &amp; CFFs</b>	
Using	3040 (26.9)
Not using	8282 (73.1)
<b>Sex of HH</b>	
Male	7347 (64.9)
Female	3975 (35.1)
<b>Age of HH</b>	
15-24	772 (6.8)
25-34	2707 (23.9)
35-44	2721 (24.0)
45-54	2165 (19.1)
55+	2954 (26.1)
Missing	3
<b>Marital status of HH</b>	
Never married	1618 (14.3)
Currently married	7123 (62.9)
Formally married	2576 (22.8)
Missing	5
<b>The education level of HH</b>	
None	2540 (22.4)
Primary	1547 (13.7)
Middle/JSS/JHS	4416 (39.0)
Secondary and above	2818 (24.9)
Missing	2
<b>Size of HH</b>	
1	2528 (22.3)
2	1828 (16.1)
3	1721 (15.2)
4-5	2976 (26.3)
6-7	1574 (13.9)
8+	694 (6.1)
<b>Number of women (15-49) in HH</b>	
0	3852 (34.0)
1	5862 (51.8)
2+	1609 (14.2)
<b>Number of men (15-49) in HH</b>	
0	7815 (69.0)
1	2868 (25.3)
2+	639 (5.6)
<b>Household wealth</b>	
Poorest	1585 (14.0)
Poorer	2149 (19.0)
Middle	2494 (22.0)
Richer	2503 (22.1)
Richest	2590 (22.9)
<b>Urban/rural residence</b>	
Urban	6161 (54.4)
Rural	5161 (45.6)
<b>Region</b>	
Western	1229 (10.9)

Central	1150 (10.2)
Greater Accra	2343 (20.7)
Volta	991 (8.8)
Eastern	1230 (10.9)
Ashanti	2049 (18.1)
Brong Ahafo	979 (8.6)
Northern	721 (6.4)
Upper East	372 (3.3)
Upper West	259 (2.3)
HH: Household Head	

### **Chi-square test of independence between the outcome variable and potential covariates**

Results from the chi-square test of independence revealed that sex, age, marital status, and education of HH, size of household, number of women or men in the household, household wealth, locality of residence, and region of residence were statistically significantly associated with the use of HP & CFFs for cooking.

**Table 3: Chi-square test of independence between the outcome variable and potential covariates**



Variables		
	<b>CF&amp;HPFs</b>	
	Not using	Using
	n(%)	n(%)
<b>Sex of HH</b>		
Male	5211 (70.9)	2135 (29.1)
Female	3070 (77.2)	905 (22.8)
$\chi^2 = 51.74$ ; Phi = -0.07; p-value = 0.000		
<b>Age of HH</b>		
15-24	519 (67.2)	253 (32.8)
25-34	1664 (61.4)	1044 (38.6)
35-44	1902 (69.9)	819 (30.1)
45-54	1680 (77.6)	485 (22.4)
55+	2514 (85.1)	439 (14.9)
$\chi^2 = 454.88$ ; Cramer's V = 0.20; p-value = 0.000		
<b>Marital status of HH</b>		
Never married	809 (50.0)	809 (50.0)
Currently married	5296 (74.4)	1827 (25.6)
Formally married	2171 (84.3)	405 (15.7)
$\chi^2 = 608.83$ ; Cramer's V = 0.23; p-value = 0.000		
<b>The education level of HH</b>		
None	2444 (96.2)	96 (3.8)
Primary	1392 (90.0)	154 (10.0)
Middle/JSS/JHS	3316 (75.1)	1100 (24.9)
Secondary and above	1128 (40.0)	1689 (60.0)
$\chi^2 = 2493.47$ ; Cramer's V = 0.469; p-value = 0.000		
<b>Size of HH</b>		
1	1537 (60.8)	991 (39.2)
2	1260 (68.9)	568 (31.1)
3	1222 (71.0)	499 (29.0)
4-5	2297 (77.2)	679 (22.8)
6-7	1329 (84.4)	245 (15.6)
8+	636 (91.6)	58 (8.4)
$\chi^2 = 464.48$ ; Cramer's V = 0.20; p-value = 0.000		
<b>Number of women (15-49) in HH</b>		
0	2782 (72.2)	1070 (27.8)
1	4243 (72.4)	1619 (27.6)
2+	1257 (78.2)	351 (21.8)
$\chi^2 = 24.10$ ; Cramer's V = 0.05; p-value = 0.000		
<b>Number of men (15-49) in HH</b>		
0	5782 (74.0)	2033 (26.0)
1	1990 (69.8)	878 (30.6)
2+	509 (79.7)	130 (20.3)
$\chi^2 = 37.23$ ; Cramer's V = 0.06; p-value = 0.000		
<b>Household wealth</b>		
Poorest	1582 (99.8)	3 (0.2)
Poorer	2135 (99.3)	14 (0.7)
Middle	2296 (92.1)	198 (7.9)
Richer	1737 (69.4)	766 (30.6)
Richest	531 (20.5)	2059 (79.5)

$\chi^2 = 5451.46$ ; Cramer's V = 0.694; p-value = 0.000		
<b>Urban/rural</b>		
Urban	3616 (58.7)	2544 (41.3)
Rural	4665 (90.4)	496 (9.6)
$\chi^2 = 1434.00$ ; Phi = -0.356; p-value = 0.000		
<b>Region</b>		
Western	906 (73.7)	323 (26.3)
Central	889 (77.3)	261 (22.7)
Greater Accra	1060 (45.2)	1283 (54.8)
Volta	834 (84.2)	157 (15.8)
Eastern	1027 (83.5)	203 (16.5)
Ashanti	1431 (69.8)	619 (30.2)
Brong Ahafo	847 (86.6)	131 (13.4)
Northern	696 (96.7)	24 (3.3)
Upper East	348 (93.8)	23 (6.2)
Upper West	243 (93.8)	16 (6.2)
$\chi^2 = 1509.46$ ; Cramer's V = 0.365; p-value = 0.000		

### Covariates of climate-friendly and health-promoting cooking fuels

We built a robust Poisson model of covariates of health-promoting and climate-friendly cooking fuels with variables that were statistically significantly related to the outcome variable in the bivariate analysis. The following factors were associated with a higher probability of a Ghanaian household to use HP & CFFs for cooking: male-headed households, households' headed by persons between 24 years and 55 years, households with heads that were currently married or never married, households with heads that have attained at least a primary level education, households with less than eight members, households with at least two women, rich households, and households in Western, Central, Greater Accra, Volta, Eastern, Ashanti, Brong Ahafo, Upper East region. Details of the prevalence ratio estimates of each covariate in the model with its corresponding 95% confidence intervals are reported in Table 4.

**Table 4: Adjusted Model of HP & CFFs for cooking**

	APR [95% CI for PR]	SE	P>t
<b>Sex of HH (Ref: Female)</b>			
Male	1.12 [1.02, 1.23]	0.05	0.02
<b>Age of HH (Ref: 55+)</b>			
15-24	1.08 [0.91, 1.29]	0.10	0.37
25-34	1.24 [1.10, 1.40]	0.08	0.00
35-44	1.20 [1.07, 1.34]	0.07	0.00
45-54	1.16 [1.03, 1.30]	0.07	0.02
<b>Marital status of HH (Ref: Formally married)</b>			
Currently married	1.22 [1.07, 1.38]	0.08	0.00
Never married / never lived together	1.20 [1.04, 1.39]	0.09	0.02
<b>Education of HH (ref: No education)</b>			
Primary	1.54 [1.17, 2.02]	0.21	0.00
Middle/JHS/JSS	2.18 [1.73, 2.76]	0.26	0.00
Secondary/SSS/SHS/Higher	3.24 [2.56, 4.10]	0.39	0.00
<b>Size of HH (ref: 8+ members)</b>			
1 member	2.10 [1.52, 2.88]	0.34	0.00
2 members	1.79 [1.31, 2.44]	0.28	0.00
3 members	1.72 [1.28, 2.32]	0.26	0.00
4-5 members	1.37 [1.00, 1.88]	0.22	0.05
6-7 members	1.18 [0.85, 1.63]	0.20	0.33
<b>Number of women in HH (ref: None)</b>			
1 woman	1.06 [0.96, 1.16]	0.05	0.25
2+ women	1.22 [1.03, 1.44]	0.10	0.02
<b>Number of men in HH (ref: none)</b>			
1 man	0.98 [0.91, 1.05]	0.04	0.57
2+ men	1.05 [0.88, 1.24]	0.09	0.58
<b>Wealth status of HH (Ref: Poor)</b>			
Rich	8.85 [6.91, 11.33]	1.11	0.00
<b>The locality of residence (ref: Rural)</b>			
Urban	1.02 [0.91, 1.15]	0.06	0.73
<b>Region (ref: Northern)</b>			
Western	2.27 [1.49, 3.46]	0.49	0.00
Central	2.25 [1.46, 3.46]	0.49	0.00
Greater Accra	2.66 [1.78, 3.97]	0.54	0.00
Volta	2.31 [1.51, 3.53]	0.50	0.00
Eastern	1.79 [1.16, 2.77]	0.40	0.01
Ashanti	2.18 [1.45, 3.27]	0.45	0.00
Brong Ahafo	1.95 [1.25, 3.05]	0.44	0.00
Upper East	1.87 [1.19, 2.94]	0.43	0.01
Upper West	1.48 [0.76, 2.89]	0.50	0.24
APR: Adjusted Prevalence Ratio			

## Discussion

The study sets out to estimate the proportion of Ghanaian households currently using CF&HPFs and delineate factors that account for their use.

The findings reveal that less than a third of Ghanaian households were using CF&HPFs for cooking. A decade ago, the proportion of households that had access to LPG was estimated to be 18% [14]. Our result show that Ghana's progress regarding access to clean cooking fuels has been slow. Since the early 1990, the government of Ghana has implemented Liquefied Petroleum Gas (LPG) program to encourage households to use (LPG) for cooking as a better alternative to the commonly used traditional biomass fuels [15]. The program has mainly undertaken safety awareness campaign, local production of cylinder and its accessories and enabling LPG accessibility to the population by distributing free LPG gas cylinders [15]. The LPG cylinder distribution was further intensified in 2013. All these programs had an objective of making 50% of Ghanaian households to use LPG for household energy need by 2015 [16], 2020 (revised timeline) [14], and 2030 (new timeline) [17]. The revision of the timelines were due to Ghana's LPG promotion program failure to meet its target. Given the current estimate and the slow adoption rate for clean cooking solutions, it will be prudent for the government of Ghana to review and evaluate her LPG promotion programs since the 1990.

The households' use of CF&HPFs were also found to be positively associated with certain household head demographic factors, household characteristics, and place and region of residence. To begin with, male-headed households were more likely to use CF&HPFs for cooking compared to female-headed households. Men have more economic advantage in most Ghanaian communities. This advantage position of men enables them to purchase CF&HPFs that are generally considered expensive in Ghana. Even though some studies present similar results, others present contrary findings. For example, one study conducted in South Asia found that female-headed households were more likely to use CF&HPFs fuels [18, 19]. The authors mentioned the ability of CF&HPFs to reduce the drudgery associated with cooking as a major influential factor for its adoption and use by female-head households.

Again, households headed by persons between 24 years and 55 years were observed to more likely to use CF&HPFs. Conventionally, persons within this age group belong to the active working-age population, granting them easier access to economic opportunities. Therefore, these individuals are more likely to afford the usage of CF&HPFs. Additionally, persons above 55 years may find it difficult and inconvenient to adopt CF&HPFs for cooking because they perhaps belonged to a generation that predominantly relied on solid fuels for cooking [20]. Other scholars also explain that the tendency to experiment and to adopt efficient modern technologies and behaviour may be a contributing factor for the adoptions and use of CF&HPFs among the younger generation [21].

Furthermore, we found that households with currently married or never-married individuals were more likely to use CF&HPFs. In today's Ghana, it is trendy for couples to rely on LPG and electricity for cooking. Also, anecdotal evidence suggests that couples may be more likely to use CF&HPFs because of its convenience. Even though undocumented in the literature, it is prudent to argue that households with never-married heads (majority of whom are young adults) were more likely to use CF&HPFs due to its

convenience and the high tendency of reducing exertion often associated with traditional cooking methods.

Moreover, we found education as another key contributing factor influencing adoption and use of CF&HPFs among households. This is because the educated household head is more informed on the environmental and health benefits of cleaner cooking fuels, which is likely to influence its choice and usage. One scholar in a similar study also opined that educated household heads in urban communities are more inclined to use CF&HPFs [22]. In addition, it is instructive to reason that educated household heads may have more access to economically viable opportunities than their uneducated counterparts. This economic advantage provides educated households with high-income levels that enable them to purchase CF&HPFs which are relatively expensive but convenient to use.

Besides, the study revealed that household's with less than eight members have a higher likelihood of using CF&HPFs. We attribute this phenomenon to the reduction in the financial burden in smaller households than larger households. Large households in Ghana are most often dominated by dependent individuals. The high demand for cooking energy uses due to the family size and the challenge of limited resources create the situation of treating the adoption and use of CF&HPFs which are most often expensive as a periphery or less of a household need due to prevailing household welfare status. Other studies confirms this finding [23-25].

We also found that households with at least two women had a higher likelihood of using CF&HPFs. In Ghana, cooking activities are mostly a preserve of adult female household members. This exposes them, (especially women without clean cooking methods) to chronic obstructive pulmonary diseases (COPD) such as bronchitis, lung cancer, asthma etc than their counterparts who adopt and use CF&HPFs. We argue that in an attempt to avert the physical drain and negative health implications associated with the burning of solid biomass for cooking, households with 2 or more adult females are more likely to combine financial resources to adopt CF&HPFs which is more convenient, timesaving and healthy. Findings from a study conducted by some authors concur with this observation [25].

Our study revealed that rich households were 8.85 times likely to use CF&HPFs compared to poor households. The adoption and use of cooking fuels like other graded commodities are highly influenced by the purchasing power of the household. The finding agrees with the Energy Ladder Theory that explains the direct relationship between the rise in household income and the adoption of clean cooking energy sources [26]. The mean annual non-food and housing expenditure for households in Ghana is GHC 4,682 [27]. Averagely, 14.5kg of LPG should suffice to meet a household's cooking and heating need. The price for 14.5kg of LPG is about GHC 80/USD 13.8 (GHC 960/USD 166 annually), representing about 21% of annual non-food-and-housing expenditure. The average annual gross income for poor households is GHC 18,191, which is 2.5 times lower than that of the rich household (GHC 44, 933) [27]. Arguably, allocating one-fifth of non-food-and-housing expenditure to clean cooking fuel will be much easier for the rich households than the poor. Again, apart from the ability to purchase CF&HPFs, there appears to be

some luxurious prestige attached with the adoption and use of CF&HPFs which rich households want to be associated with [24].

We investigated whether regional variations influenced the likelihood of a Ghanaian household to use climate-friendly and health-promoting fuels for cooking. The study observed that households within some political administrations in Ghana had a higher probability of using improved cooking methods than others. For example, we observed that households in the Greater Accra, Ashanti, Brong Ahafo, Central, Western and Eastern regions were more likely to use CF&HPFs than traditional biomass. Possible explanation for this observation can be attributed to the urbanized nature of these regions and availability and distribution of LPG gas refilling stations [28]. The Greater Accra region, for example, is the political head and administrative region of Ghana. It is the most urbanized region with about 87.4% of its population living in urban centres with access to viable economic and political resources for an improved standard of living [29]. This implies that households within these regions are more likely to utilize the available economic and political advantage to adopt or adapt climate-friendly and health-promoting fuels for cooking than their counterparts in the other regions of the country. Secondly, the reference region (Northern) has only twelve LPG gas refilling stations compared to Greater Accra (179 outlets), Ashanti (95 outlets), Brong Ahafo (70 outlets), Central (76 outlets), Western (66 outlets) and Eastern (66 outlets) regions which have over 65 refilling outlets [30], making it easier for households in these regions to have access to LPG for their household needs. These finding shares some similarities with findings of one other study [31].

Of particular interest in the above finding was the higher probability of households in the Upper East region to use climate and health-promoting fuels for cooking. This is quite revealing because households in the Northern regions of Ghana are the poorest across the country and with lower number of LPG refilling outlets. However, the likelihood of households in the Upper East regions identified in this study to use CF&HPFs suggests some qualitative explanations. In 2013, Ghana launched The Rural LPG Promotion Program (RLP) in the Upper East Region with the aim to create access to households in rural areas to use LPG for cooking [30]. The RLP involved the distribution of free gas cylinders to households [30]. It is therefore prudent to argue that many households in the region had a higher chance to benefit from the free cylinders compared with the Northern region.

The paper has certain strength and limitations that are worth mentioning. The study employed the cross-sectional analysis which did not permit the researchers to derive causal relationships between covariates and the outcome variable. It is also worth mentioning that few households were excluded from the analysis because they did not cook at home and therefore did not use any domestic cooking energy. Close to four decades, the GDHS program has been conducting its survey every five years, and this has improved the quality of the sampling methodologies, data collection procedures, and the development of the questionnaires. Given that the study used the GDHS dataset that is nationally representative and large, the estimates from the analyses can be generalized for the entire Ghanaian population.

## Conclusions

The adoption and sustained use of CF&HPFs are important in enhancing good health for nearly half of the world's population, mostly women and children in developing countries and to help protect the global environment. Our study finds household characteristics and region of residence as influential factors in the adoption of CF&HPFs in Ghana. The level of education, wealth status, age and marital status of household heads positively influenced the use of CF&HPFs. It became evident in this study that male-headed households were more likely than female-headed households to adopt CF&HPFs even though it differed from most literature. Additionally, having two or more adult females in a household positively influences the chances of using clean cooking energy. Large family size (above 8 individuals) and residence in the Upper West region of Ghana were found to negatively influence the adoption of clean cooking fuels.

To increase the adoption and use of CF&HPFs to advance Ghana's cause towards achieving the SDGs, we recommend: a national effort to subsidize and make affordable the purchase of LPG and the stoves that burn it even to the poorest household; education on efficient and sustainable consumption must be intensified and incorporated in the basic school's curriculum to ensure the future generation are more environmental sustainability and health-conscious; creation of multiple LPG refilling outlets in all the regions in Ghana.

## **Abbreviations**

CFFs: climate-friendly fuels

HPFs: health promoting fuels

CF&HPFs: Climate-friendly and health promoting fuels

NCFFs: non-climate friendly fuels

GDHS: Ghana Demographic and Health Surveys

COPD: chronic obstructive pulmonary diseases

REACCTING: Research of Emission, Air Quality, Climate and Cooking Technologies in Northern Ghana Project

HH: Households

HAP: household air pollution

SDG: Sustainable Development Goals.

## **Declarations**

**Ethics approval and consent to participate**

The Ghana Health Service Ethical Review Committee and the Institutional Review Board of ICF International reviewed and approved the 2014 GDHS protocol. Enumerators obtained informed consent from mothers between 15-49 years with children under-five years before interviewing them [11]. The GDHS did not obtain assent from parents or guardians of childbearing women who were either 15 or 16 years because they already had children and were independent of their guardians or parents. The GDHS is publicly available upon a simple, registration-access request, so no further ethical clearance was sought

## **Consent for publication**

Not Applicable

## **Availability of data and materials**

The 2014 Ghana DHS dataset supporting the analysis of this study is available in the DHS repository. The DHS datasets are available for free after a simple registration process.

## **Competing Interests**

The authors declare no competing interests.

## **Funding**

Authors did not receive any funding.

## **Authors' contributions**

DSS, AP and PLK conceptualized the study. AP and DOH performed data analysis. NKE validated the analysis. DSS, PLK, NKE, DMV, ANKH, DOH and AP wrote the paper. AP supervised the study. All authors read and approved the final manuscript.

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Not Applicable

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## Additional File

Additional file 1.docx— Proportion of households using each of the fuel types for cooking in Ghana

## Supplementary Files

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